

Clin Orthop Relat Res (2011) 469:200–208  
DOI 10.1007/s11999-010-1331-7

CLINICAL RESEARCH

# Minimally Invasive versus Classic Procedures in Total Hip Arthroplasty

## A Double-blind Randomized Controlled Trial

Jon H. M. Goosen MD, PhD, Boudewijn J. Kollen PhD,  
René M. Castelein MD, PhD, Bart M. Kuipers MD,  
Cees C. Verheyen MD, PhD

Received: 12 November 2009 / Accepted: 17 March 2010 / Published online: 30 March 2010  
© The Author(s) 2010. This article is published with open access at [Springerlink.com](http://Springerlink.com)

### Abstract

**Background** For total hip arthroplasty (THA), minimally invasive surgery (MIS) uses a smaller incision and less muscle dissection than the classic approach (CLASS), and may lead to faster rehabilitation.

**Questions/purposes** Does minimally invasive hip arthroplasty result in superior clinical outcomes?

**Patients and Methods** In this double-blind randomized controlled trial, 120 consecutive primary noncemented THAs in 120 patients were assigned to one of two groups (MIS or CLASS). The randomization sequence was stratified for two groups of surgeons, ie, those using a posterolateral approach (PL-CLASS or PL-MIS) and those using an anterolateral approach (AL-CLASS or AL-MIS). Length of the incisions was 18 cm for the CLASS

procedures. MIS incisions were extended at the skin level to 18 cm at the end of the procedure. The primary end point was the Harris hip score (HHS) at 6 weeks postoperatively. Patient-centered questionnaires were obtained preoperatively and after 6 weeks and 1 year.

**Results** For the patients in the MIS group (average 7.8 cm incision length), statistically significant increased mean HHSs were seen compared with the CLASS group at 6 weeks and 1 year. This difference was small and mainly caused by the favorable results of the PL-MIS. In the MIS group, surgical time was longer. A learning curve was observed based on operation time and complication rate. Although not statistically significant, the perioperative complication rate was rather high in the (anterolateral) MIS group.

**Conclusions** The minimal invasive approach in THA did not show a clinically relevant superior outcome in the first postoperative year.

**Level of Evidence** Level I, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at Isala Clinics, Zwolle, The Netherlands.

J. H. M. Goosen (✉), B. M. Kuipers, C. C. Verheyen  
Department of Orthopaedic Surgery and Traumatology,  
Isala Clinics, PO Box 10500, 8000 GM Zwolle, The Netherlands  
e-mail: [j.h.m.goosen@isala.nl](mailto:j.h.m.goosen@isala.nl)

B. J. Kollen  
Department of Epidemiology, Isala Academy, Isala Clinics,  
Zwolle, The Netherlands

R. M. Castelein  
Department of Orthopaedic Surgery, University Medical Center  
Utrecht, Utrecht, The Netherlands

### Introduction

After the introduction of MIS (incision length 10–12 cm or less [8, 12]) in THA, a debate started worldwide regarding the possible clinical benefits of this approach as compared with the classic approaches (CLASS) [8, 12]. The rationale for MIS is a minimized tissue dissection, resulting in reduced blood loss, pain, hospital stay, and faster rehabilitation [15]. Compared with the classic approach, the first retrospective studies showed a greater perioperative complication rate in the absence of clinical improvements in the THAs performed with a posterolateral MIS approach

[19, 23, 29]. Randomized trials showed conflicting results [3, 6, 16, 20]. However, these nonblinded studies suffered from selection, confirmation, and personal bias. Dorr et al. [8] performed the first double-blind, randomized controlled trial using a sham-incision strategy. Because of the relatively small study population, the possible benefits of MIS over the classic approach could not be established.

To contribute to a better understanding of the effects of this minimally invasive THA on clinical and other parameters, we conducted a double-blind, randomized controlled trial. We attempted to eliminate bias by blinding investigators and patients from group allocation by using a sham-incision strategy. In this study we compared the MIS and CLASS approaches with regard to the following five issues: (1) Can a clinically significant difference in clinical outcome between these two approaches be detected at 6 weeks and 1 year after surgery? (2) Does MIS result in a greater incidence of complications than CLASS? (3) Is there a difference between approaches in perioperative factors such as operative time, blood loss, or tissue injury? (4) Is there a difference between approaches in thigh circumference and body mass index (BMI) for the perioperative and clinical outcomes? (5) Are there differences between groups with respect to the radiographic measures?

## Patients and Methods

Recruitment for this single-center double-blind block-randomized controlled trial took place between January 2005 and November 2007. Patients eligible for THA were enrolled in the study after approval from our institutional medical ethics committee. We excluded patients with a BMI greater than 30 kg/m<sup>2</sup>, previous surgery of the ipsilateral hip, or age older than 75 years. After obtaining informed consent, patients were allocated (envelopes) to one of the two operations (MIS or CLASS) based on a stratified randomization scheme of two groups of surgeons, ie, an anterior approach group and a posterior approach group.

Six orthopaedic surgeons (CCPM, AKM, JJR, NJAT, CvE and AJMJ), each of whom had done more than 1000 primary THAs using the classic approach before the study, performed the operations. All participating surgeons attended a cadaveric course on MIS. Three of them performed the THA solely using the modified anterolateral-MIS (AL-MIS) or anterolateral-CLASS (AL-CLASS), in which “anterolateral” refers to approaching the hip anteriorly from the greater trochanter according to the guidelines of Frndak et al. [9]. The other three surgeons used only the posterolateral-MIS (PL-MIS) or posterolateral-CLASS (PL-CLASS) procedures, approaching the hip

posteriorly from the greater trochanter according to the criteria of Gibson [10]. The MIS procedures are described as a small-incision technique in which the quantitative skin and muscle dissection of the gluteus muscles has been reduced with respect to the classic approach [15]. Specially designed retractors and instruments were used. Otherwise, there are no fundamental technical differences between the MIS and the CLASS.

Withdrawal of a patient for any reason or any operation (including revision) leading to a new incision of the wound area resulted in premature unblinding of the patient and exclusion from the study.

When a patient was included, two instrument sets were available on standby. The corresponding instrument set (MIS or CLASS) was selected and opened based on group allocation. Next, the maximal groin circumference was obtained using a tape measure. After introducing anesthesia, skin disinfectant, and sterile draping, an 18-cm sterile curved ruler was placed on the greater trochanter. For MIS, the surgeon chose the length of the incision, usually the central part of the drawn line somewhere between 5 and 10 cm. After performing the skin incision, a first set of instant pictures was taken.

All procedures were performed using a Bi-Metric porous-coated uncemented stem and a metal-metal Magnum femoral head and acetabular shell (Biomet, Warsaw, IN). After wound closure, a second set of two instant pictures of the incision was taken, one in flexion and one in extension. Next, the skin incision with a thin layer of subcutaneous tissue was extended to 18 cm following the line drawn preoperatively and the skin was closed with staples. Surgical time, intraoperative blood loss, extension of the wound, and any adverse events were recorded on a standardized form and placed, with the obtained pictures, in a sealed opaque envelope. Systemic prophylactic antibiotics (2 g cefazolin intravenously preoperatively) and pharmacologic thromboprophylaxis (2.5 mg/0.5 mL fondaparinux subcutaneously up to 5 weeks postoperatively) were administered. A high-vacuum wound drain was used in all patients during the first 2 postoperative days. All patients received a standard dose of indomethacin (100 mg per day) during their hospital stay as a periarticular ossification prophylaxis. The standard length of hospital stay was 5 days for all patients.

All data were collected at baseline and prospectively (during hospital stay and 1-year followup) by an investigator (BMK) who had not been involved in the patients' care or surgery and was blinded to group allocation. The data were analyzed by two research members (JHG, BJK) who were not involved in the clinical procedures.

Preoperatively, demographics, baseline hemoglobin, and tissue damage parameters like myoglobin and creatinine kinase (CK) were analyzed [17]. Baseline preoperative

functional and clinical status was obtained using the HHS [11]. The patients completed three clinical patient-centered questionnaires (WOMAC [2], Oxford Hip Score [OHS] [7], and SF-36 [27]). On the first postoperative day, hemoglobin and tissue damage parameters were analyzed. Radiologic examinations of the pelvis (pubis-centered) and hip were performed. At 6 weeks and 1 year postoperatively, the patients were scored clinically and radiographs were obtained. Completed HHS, WOMAC, OHS, and SF-36 forms were obtained.

To test the effect of the blinding, at the end of the 1-year followup, patients and the investigator were asked to indicate the approach (MIS or CLASS) they thought had been used. The blinding then was lifted and patients were informed about the procedure that actually had been performed.

Radiologic examinations were analyzed at the 1-year followup. The inclination angle of the acetabular component [21, 24], heterotopic bone formation [4], femoral component position [5], and leg length difference [28] were determined.

The primary end point of this study constituted the HHS score at 6 weeks. A HHS difference of 4 points was shown to be the best cutoff point for optimal sensitivity and specificity to detect clinical improvement, as described by Hoeskma et al. [14]. Based on a Type I error of 5% and SD for the classic approach of 9.8, the sample size for the primary end point was calculated to have 80% power. To detect a clinically important difference of 5 HHS points or more between the MIS and CLASS groups, 120 patients were required for this study. Continuous variables are presented as means and SDs and categorical data as proportions and percentages in descriptive analysis.

We analyzed differences between groups with the independent Student *t*-test for continuous variables. The Levene test was used to test the assumption of equal group variance. Subgroup analyses of continuous variables were performed based on one-way ANOVA with post hoc tests using a Bonferroni correction. We used chi square and Fisher's exact tests to analyze differences between categorical variables depending on number of categories and group size. For all tests, a two-tailed significance level of  $p < 0.05$  was used. Data analysis was conducted using SPSS Version 15.0 (SPSS Inc, Chicago, IL).

## Results

One hundred twenty patients were enrolled in the study. (Fig. 1) Missing value analysis shows 3.3% of the primary end point data, HHS at 6 weeks, and 9.2% at 1 year were missing. In two cases (AL-MIS), the perioperative

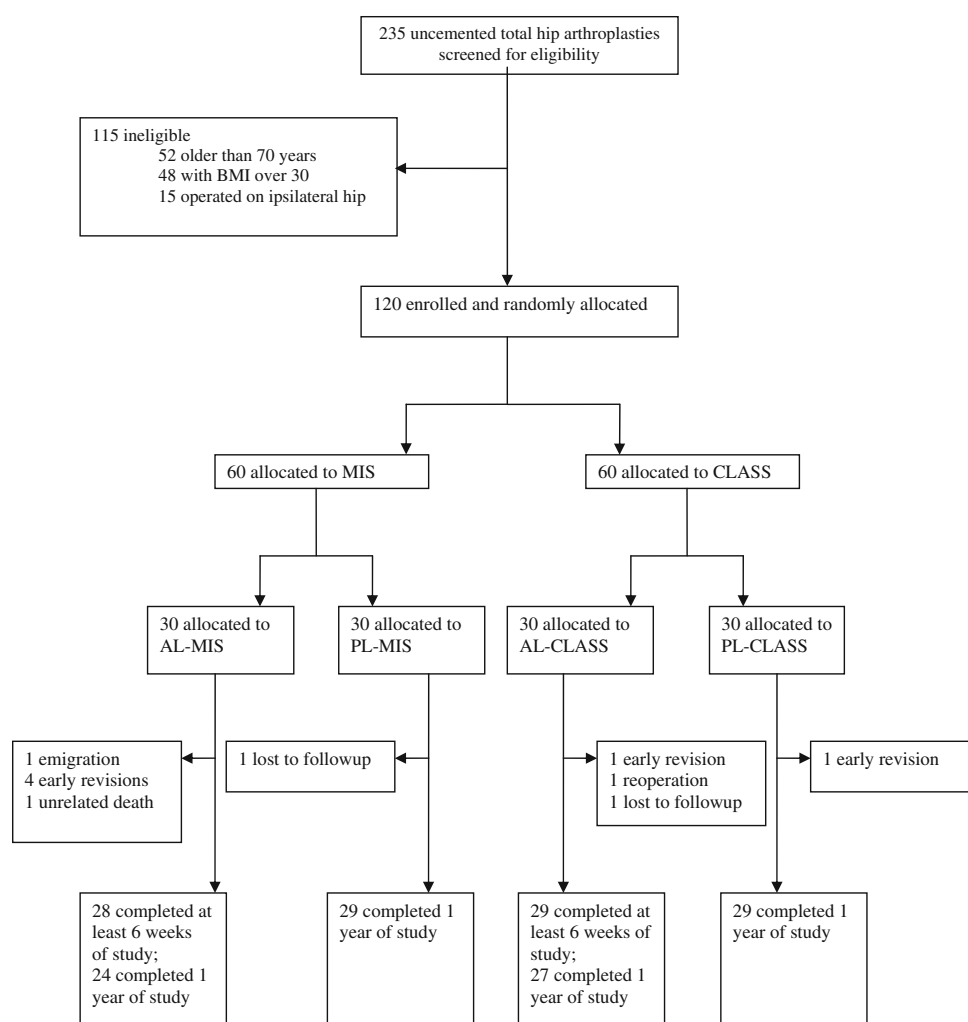
treatment protocol had to be violated; after reaming, the situation was evaluated as unfit for a noncemented cup. These patients received reversed hybrid prostheses and continued the study program according to the intention-to-treat principle. Three patients were unavailable for clinical and radiologic evaluations at 6 weeks and 1 year postoperatively (one repatriation, two revisions). Six patients were not analyzed at 1-year followup postoperatively (four revisions, one death, and one debrided infected prosthesis). After the 1-year followup, 46% of the MIS patients and 45% of the CLASS patients rightfully thought they were treated this way. The investigator correctly allocated the perceived procedure in 57% of the cases in the MIS group and 52% in the CLASS group.

Other than length of incision and mean operation time, perioperative variables were similar between the groups (Tables 1, 2). For the MIS approach, operative time was 10 minutes longer ( $p = 0.004$ ) than for the classic approach. A significant decrease ( $p = 0.028$ ) in operating time was observed during the course of the study between the first 30 MIS procedures conducted (74 minutes) and the last 30 MIS procedures (64 minutes). While performing the MIS, five procedures warranted extension of the initial gluteus muscle incision by 1 to 5 cm distally and/or 2 to 4 cm proximally. In four cases, cerclage wires were applied for a proximal fissure of the femur, and in one, venous bleeding needed to be stopped.

There were no significant differences in OHS or WOMAC scores between groups or individual surgeons (Table 3). The MIS group had higher HHS scores at 6 weeks ( $p = 0.03$ ) and 1-year ( $p = 0.03$ ) followups. Subgroup analysis showed the HHS in the PL-MIS group was significantly greater ( $p = 0.009$ ) than in the other groups. At 6 weeks followup, the SF-36 showed statistically significantly better ( $p = 0.04$ ) results for the PL-MIS group than for the other groups.

No differences in perioperative complications or reoperations were seen among the four groups (Table 4). Although not significantly different from the CLASS group (two of 60), the rate of complications in the MIS group was high (six of 60). Four of six perioperative femoral fissures occurred in the AL-MIS group. Three of them were repaired with cerclage wire preoperatively and two warranted revision within 6 months. One crack was not noticed intraoperatively and resulted in subsidence requiring stem revision. Two femoral fissures occurred in the AL-CLASS group and were wired intraoperatively. One stem (AL-MIS) had to be revised because of early aseptic loosening. For the first 60 patients enrolled in the study, a significantly greater ( $p = 0.01$ ) relative risk of perioperative complications of 2.00 (95% confidence interval [CI], 1.60–3.45) was found in the MIS group compared with the CLASS group. In the next 60 patients, the relative risk with respect to MIS

**Fig. 1** The trial profile is shown in this diagram. BMI = body mass index; MIS = minimally invasive surgery; AL-MIS = antero-lateral MIS; PL-MIS = postero-lateral MIS; CLASS = classic approach; AL-CLASS = antero-lateral CLASS; PL-CLASS = posterolateral CLASS.



was reduced to 1.36, a nonsignificant level (95% CI, 0.73–2.50).

Groin circumference and BMI did not correlate with incision length, complication rates, or radiologic or clinical results in the MIS group.

No differences in radiographic measures were observed between the MIS and classic approach THAs (Table 5). The inclination angle of the acetabular component was relatively high in the posterolateral approach compared with the anterolateral approach.

## Discussion

The aims of our study were to compare the effects of MIS and CLASS approaches on perioperative factors, complication incidence, and clinical and radiologic outcomes. We also scrutinized the effects of thigh circumference and BMI on perioperative and clinical outcomes.

Our double-blind, randomized study showed a statistically significant advantage of MIS over standard approaches in THA regarding HHS scores at 6 weeks and 1-year followups. In additional subgroup analysis, this superiority was found to be caused by the favorable results in the PL-MIS group. However, the observed differences in HHS scores were too small to be considered clinically relevant. In addition, SF-36 quality of life scores were higher in favor of MIS procedures after 6 weeks followup.

There are some limitations in this study. First, we were unable to mask posterolateral or anterolateral incisions. Although the posterolateral incision generally was made 2 cm inferior to the anterolateral incision, the shape of the incision was identical, because the same curved ruler was used. We believe blinding was successful to obtain unbiased results, because the patients failed to correctly identify a scar after classic or extended MIS. Success in maintaining blinding of patients has not been evaluated in previous studies. The second limitation is the relatively

**Table 1.** Demographic characteristics

Parameter	Approach		p Value
	MIS PL <sup>1</sup> –AL <sup>2</sup>	Classic PL <sup>1</sup> –AL <sup>2</sup>	
Hips (n)	60	60	
	30–30	30–30	
Gender (n)			
Male	30	29	1.0 <sup>a</sup>
	15–15	13–16	.89 <sup>a</sup>
Female	30	31	
	15–15	17–14	
Height in m (SD)	1.73 (0.07)	1.73 (0.08)	.94 <sup>b</sup>
	1.72 (0.06)–1.74 (0.08)	1.73 (0.07)–1.73 (0.09)	.89 <sup>c</sup>
Weight in kg (SD)	79.5 (11.0)	79.3 (11.9)	.93 <sup>b</sup>
	78 (9.8)–81 (12.1)	80 (9.2)–78 (14.2)	.80 <sup>c</sup>
Body Mass Index (SD)	26.6 (2.8)	26.4 (2.8)	.80 <sup>b</sup>
	26.4 (2.6)–26.7 (3.1)	26.8 (2.7)–26.1 (2.8)	.74 <sup>c</sup>
Age at operation in years (SD)	60 (6.8)	62 (6.6)	.13 <sup>b</sup>
	60 (6.3)–60 (7.4)	62 (6.3)–62 (6.9)	.51 <sup>c</sup>
Preoperative diagnosis (n)			
Osteoarthritis	55	59	.32 <sup>a</sup>
	27–28	29–30	.45 <sup>a</sup>
Osteonecrosis	1	0	
	0–1		
Developmental dysplasia	2	1	
	2–0	1–0	
Posttrauma	2	0	
	1–1		
Side (n)			
Right	39	36	.57 <sup>a</sup>
	20–19	18–18	.94 <sup>a</sup>
Left	21	24	
	10–11	12–12	

<sup>1</sup> posterolateral; <sup>2</sup> anterolateral; <sup>a</sup> chi square test; <sup>b</sup> independent Student t-test; <sup>c</sup> one-way ANOVA with Bonferroni correction.

short final followup of 1 year. Future studies should investigate long-term results in fully blinded patients. The third limitation constitutes our sample size for subgroup analysis, which is relatively small and may explain our inability to identify any significant differences in complication and revision rates among the four groups. The fourth limitation is the incomplete followup of seven patients from the analysis owing to reoperations. This may have skewed our results.

Previous comparative studies have not shown any differences between MIS and CLASS approaches [3, 6, 16, 19, 20, 22]. Bennett et al. [3] attempted to blind the patient and investigator by applying a bandage, resulting in a limited followup of only 2 days. Dorr et al. [8] performed a trial of 60 THAs (30 PL-MIS versus 30 PL-CLASS) by

extending the MIS incision to a length of 20 cm postoperatively. They observed a significantly shorter hospital stay and less pain on each postoperative day in the patients who had the PL-MIS procedure. However, no differences could be observed after their final 6-week followup.

In our study, overall no differences in perioperative complication rates or postoperative reoperations between classic and MIS groups were found. However, despite a lack of statistical significance, the rate of complications was higher in the MIS group (six of 60) compared with the group that had the classic approach (two of 60). Additional analysis revealed a learning curve based on the relative risk of complications during the study period. Other studies failed to show a difference or trend between the MIS and classic approaches regarding complication rates or risks

**Table 2.** Preoperative and directly postoperative results

Parameter	Approach		p Value
Groin circumference (cm) (SD)	MIS	Classic	.34 <sup>a</sup>
	PL <sup>1</sup> –AL <sup>2</sup>	PL <sup>1</sup> –AL <sup>2</sup>	.68 <sup>b</sup>
Operation time (minutes) (SD)			< .001 <sup>a†</sup>
			.004 <sup>b††</sup>
Preoperative incision length (cm)			
Hip in flexion (SD)	7.8 (1.4)	18	< .001 <sup>a†</sup>
	7.7 (1.4)–8.0 (1.5)		
Hip in extension (SD)	7.8 (1.6)	18	< .001 <sup>a†</sup>
	7.8 (1.5)–7.8 (1.5)		
Postoperative incision length (cm)			
Hip in flexion (SD)	8.5 (1.9)	18	< .001 <sup>a†</sup>
	8.6 (2.3)–8.4 (1.5)		
Hip in extension (SD)	8.4 (2.0)	18	< .001 <sup>a†</sup>
	8.6 (2.3)–8.2 (1.6)		
Perioperative blood loss (mL) (SD)	540 (321)	490 (228)	.34 <sup>a</sup>
	579 (362)–500 (273)	452 (163)–532 (279)	.36 <sup>b</sup>
Hemoglobin (mmol/L)			
Preoperative	9.0 (0.8)	8.8 (0.7)	.37 <sup>a</sup>
	9.0 (0.8)–8.9 (0.7)	8.8 (0.8)–8.9 (0.7)	.71 <sup>b</sup>
Postoperative	6.9 (0.8)	6.7 (0.9)	.34 <sup>a</sup>
	6.8 (0.8)–6.9 (0.7)	6.8 (0.9)–6.7 (0.9)	.71 <sup>b</sup>
Creatine kinase (IU/L)			
Preoperative	101 (65)	103 (45)	.85 <sup>a</sup>
	98 (34)–105 (89)	102 (48)–104 (43)	.97 <sup>b</sup>
Postoperative	485 (285)	466 (295)	.75 <sup>a</sup>
	503 (241)–464 (336)	441 (343)–495 (233)	.88 <sup>b</sup>
Myoglobin (μ/L)			
Preoperative	37 (10)	37 (10)	.70 <sup>a</sup>
	34 (6)–39 (12)	38 (13)–37 (7)	.40 <sup>b</sup>
Postoperative	195 (153)	190 (107)	.87 <sup>a</sup>
	170 (127)–222 (175)	148 (83)–235 (113)	.09 <sup>b</sup>

<sup>1</sup> posterolateral; <sup>2</sup>anterolateral; <sup>a</sup>independent Student t-test; <sup>b</sup>one-way ANOVA with Bonferroni correction; <sup>†</sup>statistically significant; <sup>††</sup>statistically significant: PL-MIS and AL-MIS vs PL-CLASS and AL-CLASS.

[3, 6, 8, 19, 20, 22]. However, these studies were done by innovators and highly experienced surgeons; thus, it can be assumed that their results cannot be extrapolated to surgeons who are relatively inexperienced with MIS.

We also observed a learning curve based on operative time. Average operating time was greater for the THAs performed using MIS by approximately 10 minutes (68 versus 58 minutes). Kim [16] reported a shorter operative time for MIS when performed by surgeons who were experienced with it. Other studies showed no difference in operative time [3, 6, 8, 19, 20, 22, 29].

MIS can stand the test of time only when, in addition to improved cosmetic appearance of a smaller skin incision, it also generates less damage to functionally more important

structures such as muscles, tendons, nerves, and blood vessels. In our study, however, no statistical difference in muscle damage parameters could be established.

Anterolateral MIS is unpopular because of the perceived direct trauma caused by detaching the hip abductors and the difficulty approaching the hip through this route through a small window [26]. In another study, patients undergoing THA subjected to an anterolateral MIS experienced significantly better hip muscle strength, faster walking speed, and greater HHS [18]. In our study, all six femoral fractures occurred in patients undergoing the anterolateral approach; four of these were in the minimally invasive group. Three of the four femoral cracks in the AL-MIS group required early revision. When taking this



**Table 3.** Clinical results

Scoring system	Approach		p Value <sup>a</sup>
	MIS PL <sup>1</sup> –AL <sup>2</sup>	Classic PL <sup>1</sup> –AL <sup>2</sup>	
Harris Hip Score (SD)			
Preoperative	58 (16)	57 (12)	.69 <sup>a</sup>
	60 (16)–56 (15)	57 (13)–57 (12)	.65 <sup>b</sup>
6 weeks	77 (12)	72 (13)	.03 <sup>a†</sup>
	80 (10)–73 (13)	70 (15)–75 (15)	.009 <sup>b††</sup>
1 year	94 (8)	90 (10)	.03 <sup>a†</sup>
	97 (4)–91 (10)	90 (10)–90 (10)	.013 <sup>b††</sup>
WOMAC (SD)			
Preoperative	47 (14)	48 (15)	.87 <sup>a</sup>
	50 (12)–46 (16)	48 (17)–48 (13)	.76 <sup>b</sup>
6 weeks	69 (16)	72 (15)	.32 <sup>a</sup>
	69 (18)–69 (12)	71 (16)–73 (14)	.73 <sup>b</sup>
1 year	82 (18)	81 (16)	.71 <sup>a</sup>
	80 (22)–84 (13)	79 (19)–82 (12)	.75 <sup>b</sup>
OHS (SD)			
Preoperative	40 (9)	40 (8)	.98 <sup>a</sup>
	39 (8)–42 (9)	40 (9)–40 (7)	.79 <sup>b</sup>
6 weeks	36 (9)	36 (12)	.66 <sup>a</sup>
	34 (8)–37 (9)	36 (11)–37 (13)	.62 <sup>b</sup>
1 year	24 (15)	25 (12)	.81 <sup>a</sup>
	26 (19)–21 (8)	27 (14)–23 (7)	.38 <sup>b</sup>
SF-36 (SD)			
Preoperative	56 (15)	58 (14)	.50 <sup>a</sup>
	60 (15)–53 (14)	58 (15)–58 (14)	.31 <sup>b</sup>
6 weeks	67 (14)	61 (16)	.03 <sup>a†</sup>
	71 (12)–63 (15)	61 (15)–62 (17)	.04 <sup>b††</sup>
1 year	80 (19)	80 (16)	.99 <sup>a</sup>
	81 (15)–79 (23)	75 (20)–86 (7)	.11 <sup>b</sup>

<sup>1</sup> posterolateral; <sup>2</sup>anterolateral; <sup>a</sup>independent Student t-test; <sup>b</sup>one-way ANOVA with Bonferroni correction; <sup>†</sup>statistically significant; <sup>††</sup>statistically significant: PL-MIS vs AL-MIS, PL-CLASS and AL-CLASS.

complication rate and reported side effects into consideration, one cannot ignore the potential risks that seem to be related to the AL-MIS approach.

Positioning of the components is of utmost importance in hip arthroplasty [1]. One concern with minimally invasive approaches is the lack of exposure could lead to less reliable positioning. We specifically addressed this issue in our radiologic followup and we observed no statistical differences. Contrary to our findings, Teet et al. [25] observed a significantly increased proportion of stems deviating greater than 2° from the neutral position in varus direction for THAs performed through the PL-MIS approach compared with PL-CLASS.

**Table 4.** Clinical results\*

Complications	Approach		p Value <sup>a</sup>
	MIS PL <sup>1</sup> -AL <sup>2</sup>	Classic PL <sup>1</sup> -AL <sup>2</sup>	
Preoperative	6	2	.08
	2–4	0–2	.24
Proximal femoral fracture	4	2	.34
	0–4	0–2	.05
Massive venous bleeding	1	0	
	1–0		
Sciatic nerve palsy	1	0	
	1–0		
Postoperative			
Infection	0	1	
		0–1	
Aseptic loosening after component revision	4	2	.34
	0–4	1–1	.10
Cup revision	0	1	
		1–0	
Stem revision	4	1	.36
	0–4	0–1	.11

\* Based on HHS, WOMAC, OHS, and SF-36 scores; <sup>1</sup>posterolateral; <sup>2</sup>anterolateral; <sup>a</sup>Fisher's exact test.

Our patient population was confined to individuals younger than 75 years or with a BMI less than 30 kg/m<sup>2</sup>. These inclusion criteria were based on the premise that patients who receive a noncemented total hip prosthesis should have a biologic age and bone quality of individuals younger than 75 years [13]. Sculco et al. [23] postulated that individuals with a BMI greater than 30 kg/m<sup>2</sup> may not be candidates for MIS because of the impaired view of the anatomic landmarks during surgery. Because the surgeons in our study were at the beginning of their learning curve, patients with a BMI greater than 30 kg/m<sup>2</sup> were not included in this study. However, no effect of BMI or thigh circumference was found in our study population.

Our study reveals a statistically significant increased HHS for patients who underwent PL-MIS and AL-MIS when compared with HSS for patients who underwent the classic technique after 6 weeks and 1 year postoperatively. The scores for the PL-MIS group were higher than those of the other groups. However, the observed small difference in HHSs lacks clinical relevance. A high rate of perioperative complications followed by early stem revisions and higher operative times were observed in patients who had an anterolateral minimally invasive approach. Although this rate did not reach a statistical level, we are concerned about this rate and its possible implications. Complication risk and operative time decreased as experience with MIS was gained. Relatively inexperienced surgeons must

**Table 5.** Radiographic measures

Radiographic measures	Approach		p Value
	MIS PL <sup>1</sup> –AL <sup>2</sup>	Classic PL <sup>1</sup> –AL <sup>2</sup>	
Stem alignment (°) (SD)	2 (2)	2 (2)	.72 <sup>a</sup>
	3 (2)–1 (2)	2 (2)–2 (2)	.08 <sup>b</sup>
Cup inclination (°) (SD)	47 (9)	47 (7)	.55 <sup>a</sup>
	50 (9)–45 (9)	50 (6)–43 (6)	< .001 <sup>b††</sup>
Grading of inclination (Sarmiento) (%)			
Grade 1	6 (10)	4 (7)	.49 <sup>c</sup>
	2 (7)–4 (14)	0–4 (14)	.18 <sup>c</sup>
Grade 2	41 (68)	49 (82)	.08 <sup>c</sup>
	21 (70)–20(70)	25 (83)–24 (80)	.39 <sup>c</sup>
Grade 3	12 (20)	6 (10)	.13 <sup>c</sup>
	7 (23)–5 (16)	5 (17)–1 (6)	.17 <sup>c</sup>
Leg length discrepancy (mm) (SD)	0.1 (8)	–0.5 (6)	.64 <sup>a</sup>
	1.5 (7)–1.3 (9)	–0.5 (6) – 0.5 (7)	.47 <sup>b</sup>
Periarticular ossification (Brooker) (%)			
Grade 1	11 (18)	8 (13)	.31 <sup>c</sup>
	3 (10)–8 (27)	4 (13)–4 (13)	.27 <sup>c</sup>
Grade 2	3 (5)	2 (3)	.50 <sup>c</sup>
	1 (3)–2 (6)	0–2 (6)	.49 <sup>c</sup>
Grade 3	0	3 (5)	.12 <sup>c</sup>
		0–3 (10)	.02 <sup>c†</sup>

<sup>1</sup> posterolateral; <sup>2</sup>anterolateral; <sup>a</sup>independent Student t-test; <sup>b</sup>one-way ANOVA with Bonferroni correction; <sup>c</sup>chi square test; <sup>†</sup>statistically significant; <sup>††</sup>statistically significant PL-MIS vs AL-CLASS and PL-CLASS vs AL-CLASS.

carefully weigh the advantages and disadvantages of MIS for each patient before deciding on a specific THA approach. The posterolateral minimally invasive approach generates the most significant statistical improvement among the four tested subgroup modalities.

**Acknowledgments** We thank N.J.A. Tulp, J.J. Rondhuis, C. Van Egmond, A.K. Mostert, and A.J.M. Janus for performing the operations and completing the study forms.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

## References

- Barrack RL. Dislocation after total hip arthroplasty: implant design and orientation. *J Am Acad Orthop Surg.* 2003;11:89–99.
- Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol.* 1988;15:1833–1840.
- Bennett D, Ogonda L, Elliot D, Humphreys L, Lawlor M, Beverland D. Comparison of immediate postoperative walking ability in patients receiving minimally invasive and standard-incision hip arthroplasty: a prospective blinded study. *J Arthroplasty.* 2007;22:490–495.
- Brooker AF, Bowerman JW, Robinson RA, Riley LH Jr. Ectopic ossification following total hip replacement: incidence and a method of classification. *J Bone Joint Surg Am.* 1973;55:1629–1632.
- Callaghan JJ, Salvati EA, Pellicci PM, Wilson PD Jr, Ranawat CS. Results of revision for mechanical failure after cemented total hip replacement, 1979 to 1982: a two to five-year follow-up. *J Bone Joint Surg Am.* 1985;67:1074–1085.
- Chimento GF, Pavone V, Sharrock N, Kahn B, Cahill J, Sculco TP. Minimally invasive total hip arthroplasty: a prospective randomized study. *J Arthroplasty.* 2005;20:139–144.
- Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. *J Bone Joint Surg Br.* 1996;78:185–190.
- Dorr LD, Maheshwari AV, Long WT, Wan Z, Sirianni LE. Early pain relief and function after posterior minimally invasive and conventional total hip arthroplasty: a prospective, randomized, blinded study. *J Bone Joint Surg Am.* 2007;89:1153–1160.
- Frndak PA, Mallory TH, Lombardi AV Jr. Translateral surgical approach to the hip: the abductor muscle “split”. *Clin Orthop Relat Res.* 1993;295:135–141.
- Gibson A. Posterior exposure of the hip joint. *J Bone Joint Surg Br.* 1950;32:183–186.



11. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg Am.* 1969;51:737–755.
12. Hartzband MA. Posterolateral minimal incision for total hip replacement: technique and early results. *Orthop Clin North Am.* 2004;35:119–129.
13. Head WC, Cuellar AD, Emerson RH Jr, Peters PC Jr. Disease and specific considerations in total hip replacements. *Curr Opin Rheumatol.* 1992;4:199–203.
14. Hoeksma HL, Van Den Ende CH, Runday HK, Heering A, Breedveld FC. Comparison of the responsiveness of the Harris Hip Score with generic measures for hip function in osteoarthritis of the hip. *Ann Rheum Dis.* 2003;62:935–938.
15. Howell JR, Garbuz DS, Duncan CP. Minimally invasive hip replacement: rationale, applied anatomy, and instrumentation. *Orthop Clin North Am.* 2004;35:107–118.
16. Kim YH. Comparison of primary total hip arthroplasties performed with a minimally invasive technique or a standard technique: a prospective and randomized study. *J Arthroplasty.* 2006;21:1092–1098.
17. Laurence AS. Serum myoglobin and creatine kinase following surgery. *Br J Anaesth.* 2000;84:763–766.
18. Lin DH, Jan MH, Liu TK, Lin YF, Hou SM. Effects of anterolateral minimally invasive surgery in total hip arthroplasty on hip muscle strength, walking speed, and functional score. *J Arthroplasty.* 2007;22:1187–1192.
19. Nakamura S, Matsuda K, Arai N, Wakimoto N, Matsushita T. Mini-incision posterior approach for total hip arthroplasty. *Int Orthop.* 2004;28:214–217.
20. Ogonda L, Wilson R, Archbold P, Lawlor M, Humphreys P, O'Brien S, Beverland D. A minimal-incision technique in total hip arthroplasty does not improve early postoperative outcomes: a prospective, randomized, controlled trial. *J Bone Joint Surg Am.* 2005;87:701–710.
21. Sarmiento A, Ebramzadeh E, Gogan WJ, McKellop HA. Cup containment and orientation in cemented total hip arthroplasties. *J Bone Joint Surg Br.* 1990;72:996–1002.
22. Sculco TP. Minimally invasive total hip arthroplasty: in the affirmative. *J Arthroplasty.* 2004;19(4 suppl 1):78–80.
23. Sculco TP, Jordan LC, Walter WL. Minimally invasive total hip arthroplasty: the Hospital for Special Surgery experience. *Orthop Clin North Am.* 2004;35:137–142.
24. Sellers RG, Lyles D, Dorr LD. The effect of pelvic rotation on alpha and theta angles in total hip arthroplasty. *Contemp Orthop.* 1988;17:67–70.
25. Teet JS, Skinner HB, Khoury L. The effect of the “mini” incision in total hip arthroplasty on component position. *J Arthroplasty.* 2006;21:503–507.
26. Wall SJ, Mears SC. Analysis of published evidence on minimally invasive total hip arthroplasty. *J Arthroplasty.* 2008;23(7 suppl): 55–58.
27. Ware JE Jr, Kosinski M, Bayliss MS, McHorney CA, Rogers WH, Raczek A. Comparison of methods for the scoring and statistical analysis of SF-36 health profile and summary measures: summary of results from the Medical Outcomes Study. *Med Care.* 1995;33(4 suppl):AS264–AS279.
28. Woolson ST, Hartford JM, Sawyer A. Results of a method of leg-length equalization for patients undergoing primary total hip replacement. *J Arthroplasty.* 1999;14:159–164.
29. Woolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ. Comparison of primary total hip replacements performed with a standard incision or a mini-incision. *J Bone Joint Surg Am.* 2004; 86:1353–1358.